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TECHNIQUES FOR EVALUATING THE LEARNING PROCESS IN ENGINEERING EDUCATION.

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THE OBJECTIVES WERE THE DEVELOPMENT OF TECHNIQUES FOR ASSESSING VARIOUS ASPECTS OF STUDENT PERFORMANCE IN SPECIFIC CLASSES, AND DEMONSTRATING THE UTILITY OF THE TRADITIONAL CUMULATIVE GRADE POINT AVERAGE. TWO DIFFERENT STRATEGIES WERE EMPLOYED--(1) A MULTIVARIATE CORRELATIONAL STUDY OF GRADING PRACTICES, AND (2) THE USE OF AN OBSERVER IN A WIDE VARIETY OF ENGINEERING CLASSES AND THE DEVELOPMENT OF A VARIETY OF ASSESSMENT DEVICES. THE COURSES WERE DYNAMICS, DESIGN, AND INTRODUCTION TO ELECTRICAL ENGINEERING. FINDINGS CONCLUDED THAT--(1) FOR A NARROW RANGE OF HIGH ABILITY STUDENTS THERE IS LITTLE OR NO CORRELATION BETWEEN ACADEMIC PERFORMANCE AND INTELLECTUAL APTITUDES, (2) A VARIETY OF VARIABLES THAT ARE ASSOCIATED WITH MOTIVATION AND ATTITUDE ACCOUNT FOR MORE OF THE VARIABILITY IN A STUDENT'S ACADEMIC PERFORMANCE, (3) THERE IS SOME EVIDENCE WHICH SUGGESTS THAT ATTITUDES OF PERSERVANCE RATHER THAN CREATIVITY ARE HIGHLY CORRELATED WITH SUCCESS IN THE ENGINEERING CURRICULUM, AND (4) CREATIVITY AND FLEXIBILITY ARE RECOGNIZED AS IMPORTANT INGREDIENTS IN PROBLEM SOLVING, BUT THERE IS LITTLE EVIDENCE OF THIS BEING A MAJOR FOCUS OF ATTENTION IN THE TRAINING OF ENGINEERS. (MB)

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Cooperative Research Project No. S-278

STANFORD UNIVERSITY
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The frankness and interest of all the students and instructors who participated in this study were sources of encouragement to the investigators. We want to thank all who gave not only their time but enough of themselves to allow us to work effectively. The study of the learning process will inevitably touch on many of our precious preconceptions. The evidence that individuals are willing to examine these preconceptions makes the future look bright for the student of tomorrow.

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Overview

A. Statement of the Problem

The goals of engineering education have been examined from time to time and are currently the subject of an extensive national study. In addition to this review at a national level, many schools of engineering are conducting studies about the characteristics of their students, reasons for the substantial attrition among their students, and the extent to which the potential talent of each student is realized.

While meaningful discussion is being generated by the studies currently underway there is an essential source of information which is continually overlooked or measured only indirectly. This information could be obtained by a detailed examination of the differential impact of the learning process for each student; the focus of attention should be on the identification of the variables which determine this impact. At present, the only measure of differential learning we have is a final grade. There is a wide variety of evidence that grades often hide more than they reveal.

The importance of obtaining this kind of information can be highlighted by discussing the influence this information would have at different levels of analysis. While the goals of an engineering education must be discussed at a policy-making level, some of the questions raised in such a discussion can only be answered through empirical research. In addition, even when goals are agreed upon, the implementation of some of these goals is dependent upon working out effective methods. In these situations and in others which will be described shortly, it is crucial to have detailed knowledge

about what is actually happening to the student. An example may clarify this point.

Two students each receive a B in a design course. Student X has mastered the techniques of mechanical drawing but could not effectively handle the more open-ended term project. Student Y turned in a brilliant term project but his mechanical drawing skills were minimally developed because he put no effort into these activities. Regardless of which point on the grading continuum we consider, it is evident that it was not an identical academic performance or learning experience which led the two students to receive the same grade.

As this situation becomes confounded by summing the grades of many courses, we end up with a very crude measure of a student's actual accomplishments. Of course this system has worked and we are committed to it for a variety of administrative reasons. This is not an attempt to replace the system but rather to elaborate upon it to meet specific needs. The need for this type of information can be examined in three separate areas:

1. The study of career choice. At present, the process of studying who stays in engineering and who leaves must stop at the door of the classroom. Yet the manner in which a student approaches the content of a course will determine his attitude toward the course and in turn his attitude toward engineering. The grades a student receives in a course are often the most powerful influence in determining a career choice. Yet these grades often offer from the student's perspective nothing more than some arbitrary judgment. This brings us to the second specific research area.

2. Teaching Process. In almost any course there are a variety of objectives ranging from the mastery of specific content to the assimilation

of subtle attitudes toward methodology and problem-solving strategy. As these goals are made explicit we can develop evaluation techniques which reflect this diversity. In addition, every student should receive a profile of his differential achievement along with his final grade. Such profiles would encourage students to think about the range of their talents and perhaps encourage them to develop areas where they have some weakness. Striving after grades might be converted into striving for self development.

The development of such a conceptual tool would also encourage instructors to make their teaching more directed at the individual needs of students.

3. Development of the full human potential of students. Beyond the development of technically competent engineers, most schools of engineering take some responsibility for encouraging students to be both socially responsible and personally creative. How this can be cultivated in the classroom again calls for a methodology which will permit us to detail the impact of the classroom on the individual student.

B. Objectives of the Study

The usual methods of evaluating a student's academic performance are inadequate in several important areas. Perhaps the most important failure is the lack of feedback provided for the student's analysis of his own performance. Ideally, any evaluation of a student's performance should, in addition, be a learning experience. Too often students receive a grade with neither information about why he received that grade nor any clues as to how he might improve his performance.

Problem-solving techniques are an integral part of nearly all engineering courses. Rather than leaving problem solving techniques to mature

haphazardly, all students could be encouraged to develop an awareness of their own characteristic modes of intellectual response. As a consequence of this awareness, students can become involved in the challenge of developing their intellects.

One objective, therefore, would be the development of a system of evaluation which would permit detailed feedback to the student of various kinds of information about his performance. This feedback would involve not only a discussion about the student's performance in a particular course but an additional appraisal in relation to his overall level of functioning. The method of transmitting this data back to the student would have to be carefully studied. Some feedback would come from the instructor but a discussion of the student's overall functioning would have to be done by someone trained in counseling. Counseling in the future will not have to take place in isolation from the academic experience of the student.

Another failure of contemporary evaluating techniques is the inherent difficulty the instructor faces in actually knowing what he is measuring. His intention may be to assess how much a student knows about a given content area, but the method used may inadvertently put some students at a disadvantage. Studying the evaluation process and describing some of the variables in general terms will eventually lead to greater refinement in evaluating techniques.

In addition to meeting the needs of a variety of practical objectives related to the immediate improvement of the educational process, several other important objectives are involved. Here we are concerned with the development of data-collecting techniques which have important research and long-range practical implications. As indicated earlier, research on

career choice and student development is limited because essential information about what the student is learning and how it effects his functioning is not available.

Furthermore, most of the research on the prediction of academic success fails because the criterion involved is so ambiguous. Detailed information about important aspects of intellectual functioning in the classroom would provide the meaningful criterion that is needed.

Still another objective of developing this type of data system would be the possibility for evaluating student development over a four year period.

C. Related Research

There are several areas of traditional psychological research which are pertinent to this study. While these areas have been developing in a parallel manner, they have never been brought together to focus on the problem of evaluating intellectual development in college students. Each area will be briefly described and then its contribution to the present problem will be outlined.

1. The Psychology of Individual Differences. In the past half century, psychologists have developed a theory of psychological testing and have produced a broad spectrum of assessment devices. These standardized tests range from the aptitude tests of the College Entrance Examination Board to Strong's Vocational Interest Blank.

The underlying assumption of these instruments is the recognition that individuals differ widely on almost any dimension that we care to observe. A second assumption states that an individual's relative standing on these dimensions can be measured and that predictions about future behavior can

be based on these findings.

While there is a vast literature on psychological testing (see Cronbach) in most instances this knowledge has not invaded the college classroom. Psychologists have written excellent texts on how to construct classroom tests but have avoided the proselytizing role of bringing their work to the attention of other disciplines in higher education (see Dorothy Wood).

Other psychologists have devoted enormous amounts of time and effort developing measures which will predict college grades. Very sophisticated statistical models have been developed to cope with this problem, but many decades of research have not provided predictors which account for much more than 50 per cent of the variance (Bloom, et al; Lindquist; Chansky). All these prediction studies have accepted the grading system and the grade point average as a psychologically meaningful criterion. The point of view taken here is that better prediction will result from more attention being paid to the criterion.

2. <u>Guilford's model for the structure of intellect</u>. Each instructor in a college has responsibility for the content and technique of his course. The policy makers responsible for putting together an entire curriculum operate on the assumption that students choosing that curriculum will be encouraged to grow intellectually and professionally. Individual instructors are responsible for evaluating a student's progress in their own courses, but no currently available system is set up to evaluate a student's total growth.

Therefore a model is needed which will allow for integrating a student's performance in one course with that in other courses taken at the same time, as well as his growth over a four-year period. This, of course, is a very

ambitious program and this research will allow for only an initial test of its feasibility.

For the last decade, Guilford has been developing both the theoretical aspects and the measuring devices for his model of the structure of intellect. This model may allow us to assess the intellectual development of the entering freshmen. We then can relate the performance on individual tests in a specific course to these general measures. Intellectual development can be studied, and, in addition, course work can be better evaluated in terms of its contribution to this development.

D. The Psychology of Problem Solving

In addition to Guilford's work on the structure of intellect, there are many contributions to the psychology of problem solving which are relevent here. In particular, we are concerned with those variables which determine whether or not an individual will be able to evaluate the important aspects of a problem and/or take a fresh perspective on the solution of an old problem. Here we are concerned with the subtle interaction which takes place between the individual's intellectual functioning and his characteristic modes of perceiving reality. For example, two individuals may have the same high level of intellectual ability but their pre-conceptions about reality are so different that their approach to a problem is entirely different. One student believes there is only one right way to do things and this way is learned from traditional authorities. The other student has learned to take traditional authority with a grain of salt and is much more flexible in his approach to a problem.

Rokeach has provided a great deal of systematic thinking and experimental evidence about the nature of open and closed belief systems. In addition

he has provided a measure of this dimension which can be used with college students.

While Rokeach has provided more systematic thinking to the problem, the literature of experimental psychology is also rich with examples of "set," which either enhances or interferes with problem solving. The experimental paradigms used in these studies could be introduced into the classroom using the content of the specific course.

Section 1

The cumulative grade point average has traditionally been the currency of the academic world. Students are continually evaluated in terms of this global measure. Many educationally significant issues are decided by a student's GPA. Hundreds of studies are reported in the psychological literature dealing with the prediction of cumulative GPA. Only recently has the utility of this criterion measure been questioned. It is the purpose of this paper to examine one aspect of the meaningfulness of the concept of cumulative grade point average. The point of view to be explored here takes as its starting point the common sense observation that both students and courses vary in the work expected and performed. Beyond this obvious point, there is the disturbing fact that two students may receive an identical grade in a course for very different kinds of academic performance. Using the grade point average as accurate reflection of the student's performance is akin to using the fun house mirror as accurate reflection of one's own appearance.

We will not come to grips with all the difficulties associated with traditional grading practices in this section. Other sections of this report

will consider more meaningful alternatives. Here we will attempt to analyze the cumulative grade point average into more meaningful segments. These segments will be created by grouping together courses which have a similarity, at least in course content. Once these segments are isolated, we can examine some of the relationships between academic performance and a wide variety of other variables; e.g., interest, personality, and aptitude.

Method

Two classes from the School of Engineering were chosen for this study. One class consisted of all those students who entered in 1961 and graduated in 1965 (N=70). The other class is made up of all those students who entered in 1963 and are currently finishing their junior year in engineering (N=58).

All grades in all courses were recorded for these two classes and then grouped according to the following principles of classification:

1. The students' overall University cumulative grade point average. (This is the traditional criterion measure.)
2. The GPA achieved by the student in his major area of study. (For this project, eight separate School of Engineering majors were included. For example, an Electrical Engineering major would have all his courses in E.E. included here, while a Mechanical Engineering major would have M.E. courses included here.)
3. The GPA achieved in the freshman history sequence of three courses.
4. The GPA achieved in the freshman English sequence plus the Scientific Writing course.
5. The GPA achieved in all chemistry courses.
6. " " " " " physics courses.

7. The GPA achieved in all mathematics courses.

8. " " " " " engineering core courses.

Results

We shall be primarily concerned with examining intra-class relationships in this study. We can, however, be more confident of the stability of our results when we find the same relationship holds over at least two different classes. The comparison of results between the two classes must be understood in the context of the differences which characterize these two samples. One sample represents a four-year graduating class, and the other represents junior class standing. Other important differences are apparent in Table I.

Table 1

Means and Standard Deviations for
Cumulated GPA, SAT Verbal and Math Aptitude Scores

Class of 1965 $\bar{X}$	Class of 1965 S.D.		Class of 1967 $\bar{X}$	Class of 1967 S.D.
574	137	Verbal	632	78
659	146	Math	705	48
-85	66	Verbal minus Math	-72	77
2.82	0.44	Cumulative GPA	2.72	0.43

We see in Table 1 evidence of a general trend at Stanford--a significant rise in the aptitude scores of the entire freshman class. Not only are the mean scores higher for the 1967 class, but there is also a restricted range of talent. Included in this table is the mean discrepancy score between

Verbal and Math aptitude. At Stanford, it is consistently found that men have much higher Math than Verbal scores. Some implications of this relationship will be examined below.

In Table 1 the cumulative GPA is recorded, using the University's 4-point system (A=4 points). Despite the large increase in overall ability level, we see that the Class of '67 is slightly lower in its overall GPA. In Table 2 the grade point averages are based on a 9-point system: 9 is A; 8, A-; 7, B+; 6, B; 5. B-; 4, C+; 3, C or C-; 2, D+, D, or D-; and 1, F. (These averages consist of all grades without regard to the number of units).

Table 2

Means and Standard Deviations for

the Various Classifications of Course Work

Class of '65			Class of '67	
$\bar{X}$	S.D.		$\bar{X}$	S.D.
5.66	2.0	1. GPA-Major	5.77	1.78
4.61	1.6	2. History	4.38	1.48
5.05	1.2	3. English	5.02	1.34
6.00	2.1	4. Chemistry	5.98	2.06
5.80	1.4	5. Physics	5.69	1.48
5.22	2.1	6. Mathematics	5.05	1.65
5.68	1.5	7. Engr. Core	5.55	1.47

When we compare the GPA's for the two classes, it seems evident that there are no dramatic changes in performance. In comparing the relative standing of the different course areas, we note that the grades achieved

in history define the low point in both cases.

Table 3 contains the intercorrelation matrix between the various GPA areas and aptitude scores for the Class of 1965. This is repeated in Table 4 for the Class of '67. Perhaps the most interesting finding is the absence of any significant relationship between aptitude and academic performance for the Class of 1965. For the Class of '67 there is a low positive relationship between aptitude and performance in both mathematics and English. In neither class is performance in engineering courses correlated with aptitude. (See Tables 3 and 4 on the following page.)

Table 3

Correlation Matrix for Overall GPA, Area GPA, and Aptitude 1965

	GPA Major	Hist	Engl	Chem	Phys	Math	Engr Core	SAT Verbal	SAT Math	SAT Discre.
Overall GPA	.34	.53	.51	.68	.76	.75	.85	NS	NS	NS
GPA--Major		NS	NS	NS	NS	NS	.24	NS	NS	NS
History			.57	.32	.43	.30	.29	NS	NS	.35
English				.33	.32	NS	.33	NS	NS	.42
Chemistry					.54	.59	.57	NS	NS	NS
Physics						.73	.78	NS	NS	NS
Math							.79	NS	NS	NS
Engr. Core								NS	NS	NS

Note: All reported correlations are significant at the 5 per cent level or higher

Table 4

Correlation Matrix for Overall

GPA, Area GPA, and Aptitude

1967

	GPA Major	Hist	Engl	Chem	Phys	Math	Engr Core	SAT Verbal	SAT Math	SAT Discre.
Overall GPA	.67	.64	.53	.69	.67	.85	.79	NS	NS	NS
GPA-Major		.37	.30	.33	.56	.54	.60	NS	NS	NS
History			.40	.41	.33	.56	.38	NS	NS	NS
English				NS	.29	.54	.42	.31	.28	NS
Chemistry					.57	.53	.53	NS	NS	NS
Physics						.52	.59	NS	NS	NS
Math							.67	.29	.31	NS
Engr. Core								NS	NS	NS

Note: All reported correlations are significant at the 5 per cent level or higher.

The overall GPA tends to have high correlations with many of the area scores because the overall GPA includes those area scores.

Performance in major area and its relationship to performance in all other areas is of crucial importance in undergraduate engineering education. Selecting a major represents the expression of the student's own choice and he should, therefore, be highly motivated. For the Class of '65, performance in major area was almost unrelated to level of performance in other areas. For the Class of '67, this changed somewhat, though no correlation was high enough to account for 50 per cent or more of the variance. We will examine the significance of this phenomenon in the discussion section.

Another set of relationships having direct bearing on undergraduate

engineering is that between the core courses and the rest of the curriculum. The highest correlations are between core courses and the mathematics and physics sequences.

One generalization which emerges upon examination of these sets of correlations could be stated as follows: The relationship between performance in one segment of the curriculum and another is so complex that in most cases we can account for not more than 50 per cent of the variance. (The square of the correlation coefficient provides a measure of the percentage of variation which is accounted for by one measure for the other measure.)

We have found that performance in one area of the curriculum does not provide as much information as we would like about performance in another area. By focusing on overall GPA we tend to deny systematically the realities of the great variability which exists in students' performance. We will now turn our attention to other sets of variables which might account for some of the variance which has been so elusive.

The evidence suggests that here at Stanford, aptitude is not significantly related to academic performance for those men who stay in engineering. In part, this can be explained by the fact that nearly all the men in these two samples have relatively high aptitude scores. It is, therefore, natural to turn to the area of motivation in order to explain the differences in student performance.

In Tables 5 and 6 we have the correlations between the different academic sectors and a variety of personality scales. The Responsibility and Achievement-via-Independence are significantly related to nearly all the separate academic areas. To generalize: students who are dependable, self-propelling, and hard-working tend to do well. This is not surprising. There

Table 5

Correlation Matrix for the CPI Scales
and Several GPA's, 1965

	Do	Cs	Sy	Sp	Sa	Wb	Re	So	Sc	To	Gi	Cm	Ac	Ai	Ie	Py	Fx	Fe
GPA Overall							.27		.25	.23				.36		.26		
GPA--Major																		
History							.24											
English																		
Chemistry							.25	.24	.26					.30				
Physics					-.27		.32		.26	.24			.30	.39		.31		
Math					-.26									.30			.24	
Engr. Core				-.24	-.29		.25		.29	.28				.40			.27	

Note:- All reported correlations are significant at the 5 per cent level or higher.

Do Dominance
Cs Capacity for Status
Sy Sociability
Sp Social presence
Sa Self Acceptance
Wb Well-being

Re Responsibility
So Socialization
Sc Self-control
To Tolerance
Gi Good impression
Cm Communality

Ac Achievement through conformity
Ai Achievement through independence
Ie Intellectual efficiency
Py Psychological mindedness
Fx Flexibility
Fe Femininity

Table 6

Correlation Matrix for the CPI Scales

and Several GPA's, 1967

	Do	Cs	Sy	Sp	Sa	Wb	Re	So	Sc	To	Gi	Cm	Ac	Ai	Ie	Py	Fx	Fe
GPA Overall							.44	.33		.30			.26	.35				
GPA-Major							.38	.34		.28					.41			
History							.31			.28				.29	.23	.30		
English							.35			.40				.37		.26		
Chemistry				-.29			.53	.29	.51				.40	.34				
Physics																		
Math							.42							.40				
Engr. Core				-.29			.38											

Note:-All reported correlations are significant at the 5 per cent level or higher.

is also, however, a significant negative relationship between the Social Presence and Self Acceptance scales and several of the academic sectors. Individuals who are comfortable with themselves and with others tend to do less well in important areas of the curriculum.

These findings suggest that the motivational variables only reveal additional complexities to the picture we are sketching. While it is true that motivation is important, it also seems to be true that only certain kinds of motivational patterns may be rewarded in the engineering curriculum. We will return to this point in the discussion.

There is one other set of relationships which is worth examining. We indicated above the lack of significant correlation between aptitude and performance. Another approach to the relationship between aptitude and performance is via the measurement of "creative thinking." In Table 7 we have the correlations between the several academic sectors and several measures of "creative thinking." (These data are available only for the Class of '67.) Eight different measures of creativity were used and only one of these had a significant relationship with more than one academic sector. Match Problems is a measure of "adapt ve

Table 7

	Making Objects	Consequences Remote	Consequences Obvious	Alternate Uses	Match Problems	Possible Jobs	Expressional Fluency	Pertinent Questions
Overall GPA					.29			
GPA-Major								
History								.32
English								
Chemistry			.30		.35			
Physics								
Math								
Engr. Core					.40			

Note: All reported correlations are significant at the 5 per cent level or higher.

flexibility" defined as an ability to redefine abstract relationship.

The score on "Match Problems" was significantly correlated with overall GPA, engineering core GPA, and Chemistry GPA. Of all the eight measures, the intellectual tasks involved in solving the "Match Problems" most nearly resemble the intellectual tasks of many engineering courses. This raises the issue whether or not we should expect other high correlations. For example, we find that the measure labeled "Pertinent Questions" is only correlated with the history GPA. It is relevant to ask how the ability to pose "Pertinent Questions" is related to the overall training of engineers. If this is important it should be reflected in the correlations with other courses.

Once again the absence of large numbers of significant correlations raises more questions for study. We had hoped that these "creativity measures" would give some clues to what was needed in order to do well in undergraduate work. Remember that the usual measures of aptitude were of no help in understanding this complex set of behaviors we label academic excellence. It would seem that the creativity measures employed here are subject to the same problems as other more conventional measures of ability. They do not reflect what talents are really being rewarded in the courses.

Discussion and Summary

An assumption underlying the use of the cumulative grade point average is that it is an accurate reflection of the student's academic performance. The ubiquitous use of this measure requires that we be very clear about what it does and does not reflect. The undergraduate curriculum in engineering is made up of many diverse segments and the evidence presented in this section suggests that mastery of one segment is no assurance of mastery in

another. This point does not deny the significant positive relationship which does exist between the different sectors. Instead, the intent is to focus on the large part of the variance which is still unaccounted for.

This focus can lead to examining some aspects of the teaching-learning process from a new perspective. The evidence suggests that a student does not work at a uniform level of performance in all courses. Perhaps this is a reality of human nature which we do not openly admit. Instead, each professor approaches his course with the view that he is presenting his material to optimally motivated students. This automatically builds in a conflict between the instructor and at least some of his students. The student has the choice of meeting the expectations of the instructor or being penalized by a low grade.

Perhaps we should work on the problem of how to create optimal motivation for all students in all courses. Some of the problems inherent in this approach will be examined in other sections of this report. At this point we are particularly interested in examining some aspects of the Stanford students' experience with the existing curriculum.

We have seen that aptitude is not significantly related to performance. In part, this can be understood to be a result of the high but narrow range of talent present among the Stanford students. Even though the narrow range of talent will reduce the possible correlation, it is also a fact that a student's aptitude has become less important in determining his current academic success than his previous academic success in high school.

What are the consequences of a student's finding that the skills upon which he previously relied for success are no longer so trustworthy? We can come up with several lines of thinking which may provide some answers.

Some students will find this new situation very frustrating. They will, therefore, respond in accord with the methods they have previously developed to handle frustration. We can see this operating in our finding that students with a well-developed sense of responsibility achieve higher grades than students with less responsibility. On the surface this makes a good deal of sense.

In the School of Engineering we would hope that such personality characteristics as "responsibility" would be related to performance. As a professional engineer, responsibility will be a key ingredient in later success. When we look more carefully, however, at the meaning of the scale we find that there is an optimum level of responsibility. Beyond that level, the person would no longer be considered responsible in the positive sense of the term. Instead, we would begin to think in terms of someone who is over cautious, unimaginative, and narrow in his ability to view problems.

We have a little further support for this line of speculation when we find that there is a negative relationship between academic performance and measures of self-acceptance and comfort in dealing with others. Another strand of evidence comes from the general lack of relationship between the Guilford measures of creativity and most academic areas.

We have been suggesting that some students do well because they grind away at all courses, not out of genuine interest but rather through a belief in the value of perseverence. Other students make the conscious decision that they will work hard in some courses because of the intrinsic worth to them and take the consequences of not working hard in other courses.

The curriculum and the associated grading practices as they are now conceived and put into practice have certain undesirable consequences. The pressure to do well forces some students either to deny or to develop their

own intrinsic interests. Instead, they choose to meet the demands of an unrelenting faculty for work which often seems devoid of significance. In addition to learning the content of the courses, these students are also trained to be obedient and uncritical.

Other students consciously decide or are unconsciously forced to be more selective in their performance. While it is true that these students are being forced to make mature decisions about how they will use their time, it is also true that they are being punished for exercising this judgment.

There is, of course, still another group of students who do extremely well in nearly everything because of a combination of high ability and strong intrinsic interests. While in the minority, there are enough of these to justify maintaining the status quo. Viewed from one perspective, these students protect the faculty from coming to grips with the reality of how most students function.

In the next five sections of this report we will examine in greater detail several aspects of the teaching-learning process. The cumulative grade point average has become a barrier to understanding the academic behavior of students. Our intent is to get beyond this barrier by assessing what actually goes on in the classroom.

Section 2

Toward the Development of an Ideal Engineering Problem-Solving Strategy

The education of engineers has for decades been the subject of lively debate and careful thought. In the past the motivation for reform has been to make what is already good, better. Presently, however, a different source of motivation is being experienced by educators. Extrapolating from the explosion of knowledge and technological advances of recent years, educators are noting the need for almost continuous education for the professional engineer. We are now confronted with the problem of how to prepare students to continue their professional learning all their lives.

It seems that a useful factor in providing students with the incentive and capability to continue training after graduation would be the possession of well-developed learning skills. That is, we assume that a student who has at his disposal a comfortable and productive strategy of learning will be likely to continue to expend the time and effort necessary to the attainment of new knowledge.

The major task of engineering students and professional engineers is solving problems. Engineering students spend the vast majority of their time learning how to and actually solving many kinds of problems in preparation for the period when, as professional engineers, they will be required to work on more problems. Therefore, the development of a good problem-solving strategy should be an integral part of an engineer's training. The present study is a first step in the direction of the development of such a strategy.

For several weeks we observed and interviewed students while they were engaged in problem-solving activities. While students varied in some of their approaches and no students were totally alike, each did implicitly employ some strategy. It is hoped that a combination of techniques and approaches will lead to the development of an optimal problem-solving strategy.

Our first face-to-face encounter with the learning environment in an engineering classroom took place during the summer session. It was our impression that a summer session class would be atypical; we therefore focused our attention on describing how students go about solving an assigned problem. Although the main focus was on problem-solving strategy, we were also very interested in understanding something of the psychological climate of the classroom.

The subjects were taken from a course in dynamics. Eight students were observed and interviewed, all upperclassmen and doing moderately above-average work in other courses. In the classroom the students appeared intent on the material being presented. It was general practice to copy everything that the professor wrote on the blackboard. Class members came well prepared for note-taking, employing graph paper, rulers, and colored pencils. Very few questions were asked from the floor; there appeared to be an unwritten rule that the students would not interrupt the presentation of a derivation or the solution of a sample problem. When questioning did occur, students seemed unskilled at pinpointing their areas of confusion.

The problem-solving behavior of the students was observed periodically throughout the school term. They volunteered to work individually on their homework problems, which constituted new material, in the presence of the researcher. While they attempted to solve the problems, they were required

to verbalize as freely as possible what they were doing. In addition, the observer asked questions when clarification was needed. The following problem-solving strategy evolved. No single student incorporated all the steps; that is, the listing is an amalgamation composed of procedures contributed by several students. The steps clearly are not independent; successful handling of later steps usually requires completion of those preceding.

1. Read the pertinent section of the text thoroughly. Beginning at this point, knowledge of--or at least acquaintance with--preceding material is presumed. Usually, for each problem there were two to five pages that were directly related to its solution. This material had to be understood if following steps were to be tackled with any substantial success. Often, more than one reading was necessary; "skim" reading was useless.

2. Work through the sample problems. Texts usually contain illustrative problems helpful in conveying understanding of the content and in solving the problems at the end of the chapter. However, thorough working-through of sample problems was--in the short run at least--time consuming and often neglected.

3. Carefully read and define the problem. This was almost invariably a major stumbling block. Problems often appeared vague, especially if the new material was not fully understood, as was usually the case. The problem typically required several re-readings at various stages in its solution.

4. Draw a diagram of the problem, indicating the direction of forces. A correct physical impression, being able to visualize what was taking place, was a valuable aid to solution.

5. Know or look up appropriate formulas. Usually it was necessary to derive additional formulas by working from general to specific equations.

6. If possible, arrive at an intuitive answer. This was labeled by one student as the "ballpark approach"; that is, attempting to get a quantitative and/or qualitative idea of the problem that was, at least, in the right ballpark.

7. Try to apply the techniques of a sample problem. This was characteristically only partially successful, as the methods illustrated in the examples often did not directly generalize to the problem at hand.

8. Continually check the work as it proceeds. The time-consuming and demoralizing effect that an error in calculation or algebra could institute made this a crucial concern.

9. See how it comes out.

Following these steps did not guarantee success. When the correct solution did not appear, or a point of blocking occurred, students began to retrace their steps. Particular emphasis was placed on a re-reading and re-defining of the problem. Often an accurate diagram, indicating understanding of the forces involved, seemed essential. Therefore, if the student was stumped, he examined and if necessary re-drew his diagram. After starting virtually from scratch, the problem was re-worked.

If an appropriate solution still was not obtained, the students characteristically fell back on another hierarchy of responses. All of them made use of break periods, ranging in time from five to thirty minutes. During their breaks, the students tried to engage in activities totally removed from study; for example, playing a quick game of basketball. Returning fresh to the problem, they were often able to figure it out. Occasionally, sleeping on a problem

seemed to make the solution easier in the morning.

Many students collaborated with other class members. Trading of solutions, joint study "dates," and other forms of mutual assistance were common, and hopeful, at least in the short run. The lone wolf was at a distinct disadvantage and his scores on the problem sets were usually slightly lower than those of students who collaborated.

Finally, if all else failed, the student would turn to the professor for assistance. A few minutes at the beginning of each class were devoted to questions on the assigned problems and were usually sufficient to clear up immediate difficulties.

There are several observations which come out of this first encounter with the learning process in engineering education. They are based on working with the students on their problem solving and also observing the general approach of the instructor. There seemed to be a great emphasis on how to do a given problem rather than focusing on those elements of the problem which might be generalized to a whole class of problems. This led to students copying everything the instructor put on the blackboard, but did not necessarily encourage them to think.

This emphasis on getting the job done is certainly a valuable part of the engineering profession; however, it may not be the most appropriate emphasis in the training of engineers. We shall return to some of these issues in section 6.

Section 3

Report on a Course in Engineering Design

Engineering has been defined by engineers as "the art of decision making and skillful approximation." Crucial to the development of talent in this art is a mosaic of factors which have come to be labelled "engineering design." It is useful to consider engineering design as some kind of process in which decisions and approximations are made which, hopefully, have a utilitarian end. That is, engineering design is what engineers do in the real world, assuming that they do not graduate into management.

Instruction in engineering, of course, involves material other than that which is directly categorized as "design." Students take courses in mathematics, physics, mechanics, electricity, etc., and the humanities. It is also supposed that students may play bridge, go to symphonies, ski, or drink beer with the boys. All the factors that make up an individual contribute, in larger or smaller proportion, to the kind of graduate that is produced.

A course in engineering design may be seen as having two functions: to act as the logical integrator of engineering education, and to inculcate the philosophy and methodology of design. Taking ingredients such as basic sciences, mathematics, communication, social sciences, etc., a design course moulds them to knowledge of analysis and design which develops into skillful design application. Students are made to realize that few real-life situations provide single-answer solutions as may seem possible from their science and mathematics courses. Furthermore, if the course is to present the basic procedure of engineering design from conception to specification, several points require elaboration. Among these are the design process, factors

motivating design, factors influencing design, preliminary design, analysis, specification, and presentation.

The course in Engineering Design was selected for observation in this study because it reflects a point of view which stirs some controversy among engineering educators. The emphasis, in a systems design approach, is placed on the fact that many problems are open-ended. Solutions must be searched for in terms of criteria which encompass a very broad range of economic and social variables. While this may be the general orientation of the course philosophy, there are often circumstances working against its implementation.

The course at Stanford is of interest because it tries to combine both the philosophy of design with the more traditional course in engineering drawing. We are interested in observing how students respond to a course with such complex goals.

At Stanford the primary, and for many students the only, course in design is Engineering 9. It is a one-quarter, four-unit, required course. Students in all classes may take the course, although for some disciplines, its functioning as a prerequisite demands its completion as a freshman or sophomore. During the autumn 1965 season, the students were divided as follows: freshmen, 56 per cent; sophomores, 30 per cent; juniors, 9 per cent; and seniors, 5 per cent. Of the 131 enrollees, approximately one-third had not declared a specific discipline as a major. Among those who had declared a major, one-third were electrical engineering, one-fifth mechanical engineering, with industrial, chemical, and civil equally making up virtually all the remainder.

As part of a current research project a representative sample of students was surveyed at two points during the quarter. These surveys, in the form of

an open-ended questionnaire, were taken near the completion of instruction in descriptive geometry and while the students were engaged in work on the first project of the course. The comments about the project were evaluated by the two laboratory section instructors.

The course instruction began with what appeared to the psychologist observing to be a flood of descriptive geometry material. New concepts, techniques, and skills were called for in rapid-fire fashion. Yet, somehow, virtually all the students (who had the advantage of the laboratory session) seemed to have excellent grasp of the material. After five weeks of instruction, over three-quarters of the students reported that they understood the material completely or had only a few minor uncertainties. There were, however, some consistent group differences in the reported level of understanding, depending on class and previous drafting experiences. As would be expected, sophomores, juniors, and seniors who have had some drafting experience (high school, college, or industry) get off to a running start. Freshmen with no experience confront the greatest difficulties, reporting a lower degree of understanding and tending to fall behind schedule on assignments. Upperclassmen with no experience and freshmen with experience tend to fall into a middle group. As shown in the following table, the class difference holds up with regard to the final grade in the course, with the ranking being seniors, juniors, sophomores, and freshmen in that order.

Table 8

Grades by Class Standing

Class	A	B	C	D	E	I	% of Students	GPA
Senior	3	3	1	--	--	--	5.4	3.29
Junior	6	5	--	--	1	--	9.2	3.25
Sophomore	10	22	6	--	--	1	29.8	3.10
Freshman	12	44	14	1	2	--	55.8	2.87

Level of understanding and enjoyment in the course do not go directly hand in hand. Not surprisingly, freshmen with no previous drawing experience enjoy the course least. The group reporting greatest enjoyment, however, is the freshmen with experience. According to self-reports, this group of students reacted favorably both to the challenge of the material and the presentations of the lecturer. Non-freshmen, with or without training, indicated average enjoyment with the course, ranking between the two freshman groups.

After the students had been working on the assigned project* for several sessions, the group differences in understanding and enjoyment became more pronounced. Freshmen reported increasing difficulty in completing work on schedule. Several freshmen, especially those without previous experience, were feeling very pressed for time. Yet most freshmen without experience continued to report satisfaction with the course. Non-freshmen maintained leadership in understanding the material, but enjoyment of the course took a downturn

* The project involved designing a conveyor belt for raising sand and rock to an above-ground container.

for many. The introduction of the project did not arouse general class enthusiasm, although it did have that effect on an estimated third of the students.

Here are some typical comments about the project, both pro and con, which impart the flavor of the reactions of the students:

"I like the chance for individuality in this course."

".....more detailed list of what is expected would be helpful, at least on a first project like this."

"...too much busy work."

"(should be) room for more design individuality; too cut and dried."

"...involves too many irrelevant facts which don't really relate to the problem."

"It gives me an appreciation of the compromises needed in engineering."

"The major weakness is that we cannot rely on mathematics to solve the problem."

"The project is much more interesting than the drawing we were doing before."

"I dislike the great inaccuracies involved in the descriptive geometry."

Several students, however, went beyond merely commenting on the project and offered statements about the course and their reactions to it. While most of the remarks were additional positive statements, a significant number of students used the questionnaire as a vehicle for expressing the difficulties they were experiencing. It is likely that such confusion is not limited to Engineering 9 but occurs throughout the curriculum. The following are some examples of the comments:

"...the lectures are not adequate to prepare you for the lab. This course is supposed to be a design course but it turns out to be a course where all you do is rush to get the project done." (Upperclassman)

"It is unfortunate that certain engineers who will not be behind a drawing board in business are forced to put in many long hours in the lab. True, everyone should know how to read basic drawings, but it is not necessary to labor over intricate problems in order to gain this basic knowledge." (Upperclassman)

"I don't feel that we are given sufficient background before we are given assignments." (Freshman)

"I am not enjoying the work, nor do I comprehend it." (Freshman)

"The course is basically obvious but requires a truly clear and logical mind, one which I haven't yet developed. Any help along this line would be appreciated." (Freshman)

"The complexity is not softened in the explanation by the T.A.'s" (Upperclassman)

"...beyond our preparation in previous courses." (Upperclassman)

"I don't think that the instructors have made a good estimation of either the capabilities of the students or the speed at which they work." (Freshman)

These comments are from students in trouble. The number of such students is small when compared to those who do not express confusion or difficulty. It should, however, be a fundamental principle of teaching that instructors can and must attempt to reach students who are basically bright, studying in their chosen field, yet experiencing difficulty.

Some of these students actively seek assistance. Most, according to a survey of another engineering course, first look for help from their classmates. Eventually, a small portion of students in trouble talk with the professor. Yet it is painfully obvious that going to the professor is the last resort of most students. All instructors have experienced the frustration of seeing a student for the first time after the final is over and as the young man clutches his blue book with an "F" on the cover. Usually, the frustration of the instructor is heightened by the memory of weekly office hours spent alone. Somehow the instructor's statement, "But I was available all quarter," echoes as feebly as the student's reply, "I thought I could do it myself." Obviously, as such experiences recur for the students (although for some, once is enough) engineering loses its appeal.

One purpose of the survey of Engineering 9 was to determine the effectiveness of a questionnaire in opening channels of communication between the students and instructors. The degree of openness in response and the enthusiastic participation of both students and instructor indicate the potential usefulness of the technique. A questionnaire has several advantages from the students' viewpoint: it is fast, yet permits open-ended comments; it is anonymous (or could be); and it does not demand face-to-face confrontation with a possibly threatening professor. For the instructor, such an instrument is easy to prepare and administer, provides an over-view of the class's progress and difficulties, and may supply some helpful teaching advice. To the benefit of student and instructor, a questionnaire may serve as an "introductory" mechanism, facilitating personal contact. Several students, for example, expressed surprise, relief, and pleasure that their opinions were being taken into account by the instructor.

If the students who are experiencing difficulties in any course are to be helped, they must be convinced of the instructor's availability. Perhaps the implementation of weekly or biweekly requests for the students to evaluate the course and their progress is a step in the right direction.

Concentrating on the students alone, however, does not seem sufficient. The instructors must feel that such contact is useful and rewarding and, furthermore, must be comfortable in what may be a relatively new role. An instructor may find it necessary, for example, to act not merely as an importer of knowledge, but as a counselor as well. It is even conceivable that an instructor and a student, by working together, may come to the conclusion that a student should leave engineering. For a student who is in the process of making such a decision, the support of an understanding faculty member can be extremely helpful. Similarly, for the student who decides to persevere, the backing of an interested professor may make the difference between success and failure.

Returning to the discussion of Engineering 9, the data make possible some tentative conclusions and suggestions. Within the context of a course which teaches the tools of descriptive geometry, it is very difficult to "inculcate the philosophy and methodology of design." A great many students perceive the course in terms of drawing, rather than design. Such an interpretation is not without justification, as a good deal of time is focused on the techniques of drawing. Elements of design, conceived in terms mentioned above, are present but not to the degree hoped for by the instructors.

Students in a course such as this are confronted with a confusing set of goals. Mastery of the technical skills of drawing is set up as one requirement. Yet many students see this as conflicting with some of the broader

issues that are touched on in the course. Inadvertently the student who is more task-minded and meets the explicit requirements of the course will be more highly rewarded than the student who wants more challenging problems and thus remains unmotivated.

The implementation of a system of written feedback to the instructor permitted some expression of student attitudes. This is a valuable first step but students also need to have these attitudes recognized in terms of specific changes in course content. The issue of change in course content is both complex and important. The needs of the student cannot adequately be met by considering only one course but requires an evaluation of the intended goals of the entire curriculum. This is beyond the scope of this study, but some of our conclusions will have a bearing on this topic.

Section 4

Differential Effectiveness of Small Problem-Solving Sessions

Different teachers may have differential effects on their students. In order to test this proposition in engineering courses, a survey course in electrical engineering was selected for investigation. A major function of the course was instruction in the solution of problems involving use of knowledge of electricity and related techniques. Content was presented in thrice-weekly lectures. Of interest in this report, however, are the problem-session groups, three in number, each meeting once a week for two hours. Each group was taught by a different instructor; one by the lecturer, an experienced member of the faculty, and the others by recent Ph.D.'s with little or no teaching experience. It was hoped that data could be obtained from the problem sessions pertinent to differential teacher influences on students.

After preliminary observation by a psychologist and an assistant from the School of Engineering, a questionnaire was developed and administered at the end of the term to a sample of the class. (See Appendix). Three sections of the questionnaire will be discussed here:

1) Basic demographic data

2) An open-ended statement of opinion of the problem sessions

3) A dimensional rating of the problem-session instructor.

Group I was instructed by the class lecturer, while Groups II and III were taught by his assistants. The sampled N of 40 represents about two-thirds of the class enrollment. (Demographic data are presented in Table A--see Appendix)

The data in Table A (see Appendix) indicate that the make-up of the three sections was similar in most respects. Age differences were not marked, although Group I appears to have had a few more of the younger class members. Distribution of disciplines was somewhat restricted in Group III. The groups were almost identical in their plans for graduate training, and virtually all students attended the lectures. Attendance at the problem sessions was somewhat better in Group I than in either of the others.

The students' descriptions of their problem sessions are presented in Table B (see Appendix). The opinions of the students were rated by a psychologist judge as good or bad and then rated on a one-to-nine dimension of "goodness" or "badness" by the same judge. Group I received more statements judged as "good" while Group III obtained more comments judged "bad," Group II falling between in both instances. The means and standard deviations of the "good" ratings are listed in Table C and the data on the "bad" ratings are given in Table D (see Appendix).

Referring to the "good" ratings, Group I is rated significantly better than Group III ($t=2.60$, $p<.01$). Group I is also rated better than Group II, although not with statistically significant magnitude ($t=1.33$, n.s.). Clearly, however, Group I was viewed with greatest favor, while students made fewest "good" comments about Group III.

Table D illustrates that Group III received the greatest number of "bad" comments, Group II an intermediate amount, and Group I the least. The difference between Group III and Group I is significant ($t=3.43$, $p<.01$), while that between Group II and Group I approaches an acceptable level of significance ($t=1.97$, $p<.07$). The difference between Groups II and III is not significant ($t=1.42$, n.s.). The "good" and "bad" ratings combined make it

reasonable to conclude that the students viewed Group I most favorably, Group II second in desirability, and Group III lowest in attractiveness.

If the instructors were influential in affecting the students' ratings of the problem sessions, it would be expected to show up in the instructor ratings. That is, the ratings would be expected to be most favorable for the Group I teacher, least favorable for the Group III leader, and intermediate for the Group II instructor. The mean ratings illustrated in Table E substantiate these expectations. The professor teaching Group I was described as active, having a good sense of humor, interested in others, likeable, helpful, fair, respectful of students, intellectually quick, and rewarding.

The Group II leader was seen as encouraging of discussion, flexible, sensitive, intellectually quick, and showing respect for students.

Group III instructor, however, was granted only intellectual quickness as a positive feature, the rest of the rating profile being rather flat. Thus, it does appear that feelings about the instructor are highly influential in shaping the opinions which the students hold with regard to the problem sessions.

Furthermore, on the Problem-Orientation Questionnaire (see Section 5), the students in Groups II and III stated lower opinions of the problem sessions than those in Group I, considering them as a waste of time, less helpful than discussions with fellow students, not contributing materially to understanding of the course, and not usually clearing up difficulties.

There are, however, indications of unexpected differences in the course performances of the three groups. All students took the same mid-term and final examination and were graded on a single curve. The students with the highest course grades were those in Group III.

Table 9

Final Course Grade by Problem-Session Group

	Mean Grade	SD
Group I	2.58	.77
Group II	2.54	1.00
Group III	3.20	.75

The differences between groups are not statistically significant (III vs. I, $t=1.90$, $p<.10$; III vs. II, $t=1.74$, $p<.10$), but the direction is strong enough to warrant the raising of some questions. First, did Group III contain better students to begin with? Apparently not, as the overall grade point averages were Group I, 2.57; Group II, 2.82; and Group III, 2.71. Also, the difference in course grades cannot be attributed to the slightly larger number of younger students in Group I, for these students as a group did as well as older students.

Second, is the attitude toward the problem sessions and the instructor reflected in total course performance? If so, the relationship is complex and indeterminate from these data. Furthermore, it is painful to contemplate that instructors perceived as "good" do not influence their students to receive higher grades. Clearly, however, there is no direct relationship between positive attitudes toward the problem sessions and high course grades. It is possible that students in poorly-perceived problem sessions react by working harder on the regular course work, thereby raising their grade. Similarly, perhaps students in highly-rated sessions tend to take it easy and let course work go. Also, however, it is possible the grades serve as an inadequate criterion of attitudes such as interest and excitement. That is, such qualities may not be rewarded by the present grading structure and their generation by the instructor if the student receives no overt reinforcement.

There is usually a plea for having excellent instructors in the undergraduate curriculum. There is also some evidence that students can agree about the dimensions which characterize a good teacher. Students state that they enjoy the course more when they have good instructors. Do they also work more effectively and learn more? This is clearly the important question and no straightforward answer is available.

Part of the reason we don't know is the result of the very issues we are discussing in this report. Too often teaching is thought of only in terms of what the teacher does while actually teaching. If evaluation is not considered a vital element in the teaching process, then there are at least two serious consequences. Not enough thought is given to what is being measured and the students' reaction to the measurement process is often disregarded. Learning and getting good grades are too often distinct processes because teaching and evaluation are often separately conceived. In the next section we will examine some of the attitudes of students to some of the standard ways of evaluation present in the engineering curriculum.

Section 5

Responses to a Problem-Orientation Questionnaire

This initial instrument attempts to measure some attitudes and behaviors of engineering students related to the solution of assigned problems. The items are aimed at eliciting the students' reactions to problem sessions and session instructors, the problems themselves, and problem-solving methodology.

The questionnaire was administered to a sample of 40 students from a course in introductory electrical engineering. Subjects were predominantly juniors and seniors; no freshmen were taking the course. There were representatives from the electrical, mechanical, industrial, and civil disciplines of engineering. The questionnaire was included among other measurements of student attitudes.

The responses of the students are presented in Table 10 at the end of this section.

A majority of the students considered the problem sessions, which were conducted by the lecturer and two assistants, all Ph.D.'s, to be of some use. Almost unanimously, however, the students thought that the success of a problem session depends largely on the instructor. It is worth noting that students in the session taught by the lecturer, who was rated as an excellent teacher, had consistently better impressions than those instructed by the teaching assistants. (See Section 4 of this report, "Differential effectiveness of small problem-solving sessions.")

Half the students wish, for example, that grades were not so dependent upon their ability to work problems, and 70 per cent admit that they some-

times get sick and tired of doing nothing but problems. Yet the great majority are responsible about getting assigned problems done on time. It should be noted, however, that hardly anyone does additional problems for self-edification. Apparently, the interest in solving problems is satiated for most students by assigned work, and spare time is spent on other activities.

The importance of problem-solving for examination purposes is fully recognized, although not with a great deal of relish by many. Almost all students review problems before a test. On tests where speed of problem-solving is a major factor, three-quarters of the students harbor feelings of resentment, usually expressed in terms of "If I had had more time I could have done much better." Clearly, examinations which emphasize speed alienate a good many students, and perhaps their utility as determinants of grades should be reconsidered.

Most students share a common problem-solving behavior pattern. Although study breaks are widely employed, persistence appears to be a typical characteristic. Inability to solve an assigned problem results in real frustration for half the students, but hardly any lose sleep over it. Working through the sample problems, a highly recommended technique, is adopted by very few, primarily, it is claimed by the students, because of time pressure. Probably the only way to encourage students to do the sample problems would be to prove their time-saving efficacy. The almost unanimous belief that a general problem-solving strategy exists points up the necessity for the development of and instruction in an optimal approach to problems (see Section 2, "Toward an Ideal Problem-solving Strategy").

Table 10

Problem Orientation Questionnaire

Per Cent responding			
TRUE	FALSE		ITEM
22.5	77.5	1.	Problem sessions are usually a waste of time.
15.0	85.0	2.	I almost always do more problems than just those assigned.
92.5	7.5	3.	I take study breaks when I am working on a set of problems.
90.0	10.0	4.	I usually get my problems done and handed in on schedule.
92.5	7.5	5.	I always review problem-solving material just before a test.
90.0	10.0	6.	The success of problem sessions depends largely on the instructor.
37.5	62.5	7.	I learn more from talking to fellow students than I do in problem sessions.
82.5	17.5	8.	If a problem session is taught by the regular lecturer in a course, I try to get into that one, rather than one taught by his assistants, even if they are Ph.D.'s.
72.5	27.5	9.	Sometimes a good class lecturer isn't very good at teaching problem-solving.
10.0	90.0	10.	Each problem must be approached individually; there is no generally applicable problem-solving strategy.
70	30	11.	The ability to solve problems is what engineering is all about.
10	90	12.	Most professors of engineering are poor teachers.
70	30	13.	If a problem stumps me, I keep plugging away at it until I solve it.
55	45	14.	I wish that grades were not so totally determined by ability to work problems.
67.5	32.5	15..	Problem sessions materially contribute to my understanding in a course.
10.0	90.0	16.	I always try to work sample problems before I do the regular assignment.

Table 10 continued

TRUE	FALSE		ITEM
72.5	27.5	17.	I rarely consult with an instructor during his office hours.
60	40	18.	I usually try to arrive at an intuitive answer to a problem before proceeding with a formal solution.
75	25	19.	I resent examinations in which speed of problem-solving is a major factor.
70	30	20.	Sometimes I get sick and tired of doing nothing but problems.
40	60	21.	It is virtually impossible for me to do problems effectively on Saturday night.
15	85	22.	I often briefly review the day's work just before I go to bed at night.
15	85	23.	I have had practical engineering experience which has contributed to my ability to solve problems.
35	65	24.	Examinations in which the grade is determined entirely by the ability to solve problems accurately measure a student's knowledge of the course material.
52.5	47.5	25.	I really get frustrated when I can't solve an assigned problem.
25	75	26.	Instructors should put more emphasis on theory than on solution of problems.
35	65	27.	One of the characteristics of good problem solvers is the ability to isolate oneself, sometimes for hours at a time.
65	35	28.	Problem sessions usually clear up difficulties I may have had.
15	85	29.	I have difficulty going to sleep at night when I have been unable to do some assigned problems.

Section 6

Some Innovations in Teaching a Section in Electrical Engineering

Most of the work in this study has been descriptive. Either student observations or the observations of the investigator were used to describe many facets of the teaching-learning process. Several problems had been identified, and it now seemed possible actually to work with an instructor to help him teach more effectively.

In an attempt to investigate the effectiveness of some innovations in teaching techniques, a small section of an electrical engineering course was selected. The class was composed of eight volunteer students from a larger class of about sixty students. They were informed that some informal experimentation in teaching methods would be tried, but the class would cover the same amount of material as usual. The instructor was a Ph.D. candidate on his first teaching assignment and very amenable to trying out various approaches.

From the earlier observations of other classes, it was felt that communication between teacher and student could be improved. At the beginning of the quarter this was briefly discussed with the entire class. All agreed it would be desirable to work at improving communication. One approach was to reserve a few minutes at the end of each class session for student evaluation of the presentation of material and other classroom activity. These notes were given the instructor at the end of each week.

The instructor was asked to facilitate communication by organizing the presentation of his content in such a way that there would be natural stopping

points. At such points he would pose a question about the material just presented and ask all members of the class to write their answers. After a few minutes for each student to think about the question, there would be a general discussion of the correct solution.

Typical of the kind of feedback received by the instructor are the following notes from one of the students:

1/28/66 Friday--very good lecture. A little time was wasted at the beginning, but on the whole, the lecture was well planned and very easy to follow. I like the use of questions during the lecture.

1/31 Monday--I agree with the general criticisms and comments from last week. Excellent lecture again--well organized and well given. No delaying at all and covered all we were supposed to cover--really a great lecture.

2/2 Wednesday--Class went a bit more slowly today, probably because it was quite a bit of review. The "question" technique was especially helpful today. Lecture was very well organized.

Friday--Missed

2/7 Monday--Good lecture.

2/9 Wednesday--Midterm--much too long to be really useful.

2/11 Friday--Good lecture. I liked the use of summary but missed the "old" technique a bit; e.g., use of questions during the lecture.

From our work in other courses it became clear that "problem-solving strategy" was an inherent part of the curriculum. It was never emphasized, however, in a manner which made the student aware of the process. Problem-solving strategy seemed to be taken for granted or was imbedded in the content

of the course. Our previous observations suggested that the problem-solving methods of many engineering students were quite disorganized. Students rarely approached their typical problems with any definite plan of procedure.

It seemed desirable, therefore, to make the discussion of problem-solving strategy an explicit goal of the course. Students were asked to discuss their procedure for solving particular problem sets. This statement included a time-allotment schedule: each student was to indicate the time spent in initial thinking about the problem, including efforts which led to incorrect results.

After the first problem set was turned in, the instructor led a general discussion about problem-solving methods. The need for spending more time thinking before plunging in was repeatedly emphasized. Along with this was emphasis upon having a clear plan for systematically attacking a problem. For each problem set turned in to the instructor, he would make comments about the student's problem-solving strategy. The instructor in his written comments would raise questions about why the student took one approach rather than another.

In an effort to focus on these strategies in the classroom, the instructor's questions were so framed as to illustrate the general approach. For example, students were sometimes asked to anticipate the next step on the basis of previous information. In the presentation of a circuit system, for example, students would be requested to provide some of the appropriate components.

Another approach to the improvement of communication was periodic review of the material by the instructor. For example, after three lectures on analog computers, the teacher briefly presented the main concepts, techniques, and uses. Before the midterm and final examinations, all preceding material was summarized. Abstracts were offered in highly organized outline form,

logically condensing the material to only the most crucial points.

In a course in which communication between student and instructor was a focus of attention, it seemed natural to seek student reaction to the midterm examination. Students were asked to evaluate the examination and also describe how they prepared for it. Two examples of this midterm critique are provided here.

Midterm Critique (1)

I was not very impressed with this midterm. I do not think it was a true test of my knowledge of electricity. My reasons are:

1. It was much too long. I was required to work so fast on a couple of the problems that I made careless mistakes resulting in the loss of 8 points on problems that I had no trouble working on homework assignments or practice problems. I am referring in particular to the ninth problem--block diagrams--where I lost 3 points and probably should have lost more because of my mistake. On the second problem, concerning operational amplifiers, I lost 5 points for forgetting to put down the initial conditions--again fairly graded--but nevertheless, the rush I was in left me no time to double check any of my answers. This is my main complaint. I realize that the careless mistakes were my fault, but I know if I had been given 15 minutes more, I would probably have been able to increase my grade by 30 points (8 for the careless mistakes on 2 and 4; 10-14 points on Problem 1, where I started the problem and had most of the pertinent information figured out but couldn't see the graph so I went on, intending to return to the problem at the end--I forgot to go back; and 10 points on the second half of problem 5 which I didn't even have a chance to look at!)

What the criticism amounts to is that I got too rushed by the midterm to do a good job on it. As far as I can tell, I feel my grade depends tremendously on how lucky I was when I took the test. If I'm really lucky, I won't make any careless mistakes (which have always been a weak point with me), but if I'm not so lucky my grade can drop as much as two letter grades. I really do think that luck does play a large part on such a midterm.

The midterm did have its good points, though, I felt that it was very good in its coverage of the material considered important for the course. There was nothing on the midterm that was surprising and all major points were covered--excellent midterm in this way.

Answers to Questions (critique 1)

2) Was it graded fairly? Yes on the whole, though I don't see how I got such a low grade on problem 3.

3) Time spent studying for midterm? About 12 hours.

4) Study procedure?

a. Read text and took notes on text

b. Read class notes

c Reviewed all problems and understood all of them

d Tried some problem-session problems

I feel this is an effective way to study for an engineering midterm

5) I have been spending 2 3 hours a week <u>studying</u> for the course

This student then went on to observe:

One thing that would help the course considerably is well organized problem sessions. I have given up going to my problem session because in the first four weeks I don't think I learned anything more about Engineering 41. The instructor seems to know the material quite well but cannot teach it at all

For instance, the session dealing with analog computers was held before analog computers were assigned in class. As a result, I didn't have any idea of what was going on, and the instructor was not able to explain it in simple enough terms. All he seemed to be doing was placing resistances and capacitors in a peg board type instrument. At the time, I didn't even know what an analog computer was used for!

Midterm Critique (2)

In response to the midterm recently administered, I think it was as good a test of the material covered as could have been accomplished with problems. But I disagree with what seems a basic belief of the Engineering 41 and 42 series: that the ability to work problems demonstrates accomplishment in Circuits and Electronics. As a requirement for all engineering students, why does technical manipulation have to play such a large part in student evaluation? As a survey course, much more of a general nature should be asked of the students, both in homework and tests. As it is now, it seems to create a large hurdle or initiation step for Stanford engineering graduates. I have retained little of what I had memorized for Engineering 41. This was demonstrated in test question #3 by my inability to successfully derive a Thevenin equivalent. I doubt that I will remember and be able to work half the problems that many people will expect of me. This situation seems inconsistent with the emphasis of the course.

In studying for the midterm, I looked at the problem sets and scanned the text for about six hours. During normal weeks, I have been spending at most one hour studying for 42 without a goal of being able to do the problems. This is too little, but if the amount of time spent on the problems was less,

I could feel I could do more of this general studying.

I thought studying problem sets was the best way to prepare for the mid-term. I still do, since it was all problems, but I admit a better understanding of principles would have helped. I found time was too short. I left #1 until last and merely put down what I hoped was the right way to approach it with little time. This rush also caused me to overlook #5. I should have done something more valuable with #3, but it was sufficiently different from the homework that I was unable to do so, although I spend a lot of time on it. Numbers 4 and 2 were appropriate; I made some careless mistakes.

The test was graded fairly; I have no complaints. I think the students in the main section were treated too generously with partial credit. But it does seem that something substantive is wrong if, with realistic grading, students cannot average more than 45 per cent on a test. (End of student comment).

These critiques are instructive from several different perspectives. First of all, it is impressive to see how much effort students are willing to expend on such a task. It is clear that a great deal of feeling is built up as a result of being examined. The second point is a little more difficult to articulate. It would seem that the student, in effect, makes an implicit contract with his instructor about what he wants to learn and how he should be expected to reveal his learning. The two examples presented here demonstrate how differently students conceive of this contract.

The third point is related to the second. Students, when confronted with a test, evaluate it not only in terms of their implicit contract but also in terms of fairness. Here the student shifts from his personal per

spective and tries to evaluate the test in the light of what the instructor was trying to accomplish.

We have seen in other sections of this report evidence of the discrepancy which exists between what the student wants and what the instructor is prepared to give. In order to pursue this question a little further, several students were interviewed toward the end of the quarter. We were interested in determining how a student integrated what he learned in one course with his total experience in the undergraduate curriculum. We asked: Of what significance is this course with regard to your engineering career? One student suggested this course would be like Spelling for an English major; it is essential. Another felt a basic course of this type is all right, but this one i- just too complex.

Again, there are large individual differences between students, and these differences affect the way a student will respond to the course material. This point can be illustrated by examining several students' responses to the following question:

> What influence has this course had on your attitude toward electrical engineering? On your attitude toward engineering in general?

A Can't get up enough interest. It's too hard. I think I can get the concepts, but the problems are too hard. E E majors get the material later anyway (Major: I E. Course grade, B)

B Need electrical engineering for mechanical engineering. Makes it easier to understand M E, since work with a lot of E E equipment. It hasn't influenced me at all. There is a distinct difference between upper and lower classes. In lower division (like this course) you have to cram it in and see what you retain. They throw everything

at you--I don't like it. Upper division is better--work with basic principles. (Major: M.E. Course grade A-)

C. Has given me a basic approach to problems. I write what the given is--then what I want to find out. Don't do detailed steps any more, but I do write basic concepts and how to use them. Hasn't increased speed, but I feel more organized. (Major: M.E. Course grade, B+).

Most of the students in the course felt it was very worthwhile, both in terms of what they learned and from the perspective of an interesting adventure in learning. The long-heard cry for more teacher-student interaction was satisfactorily met. Nevertheless, some students were uninterested and could not be drawn into the learning process. We mention this only to illustrate the point that some students, at a given point in their lives, will not be open to learning.

Of greater significance is the varying degree of dissatisfaction that students who did well in the course felt with its general philosophy. Here students were not complaining about how things were being done. We know that overall they were fairly well satisfied. Instead, they were raising questions about <u>why</u> they were being expected to learn this way in the first place. The large amount of material and the necessary memorization that went with it were not congruent with their wishes.

We have been concerned with examining the effects of encouraging more student-teacher communication. Overall, this seems both desirable and beneficial to the learning process. It does seem to open Pandora's box, however, because the students begin to raise fundamental questions about the aims of a given course and the goals of the undergraduate curriculum.

Conclusions and Implications

Teaching is one of the major functions of the faculty. The goals of these teaching efforts can be described at different levels of analysis. At one level the primary goal of the instructor is the presentation of the specific content of the course. It has been the intent of this report to demonstrate that the methods used in presenting the content of the course and the methods used for evaluating a students mastery of the course content have far reaching consequences. The full extent of these consequences can only be understood if we move to another level of analysis. Here we have to examine the goals of the entire curriculum. Only then can we examine what contribution a given course is making toward that goal.

It is generally agreed that mastery of the content of the curriculum is only part of the larger goal of the curriculum. The other parts are a little more elusive when we try to define them and even more elusive when we try to implement them. The following is one statement of these larger goals: "We must encourage our students to learn to think independently, evaluate their own and others' work with high critical standards and be free enough to see creative alternatives. We must also encourage in our students the motivation to continue learning and to actively pursue their own intellectual curiosity. We must also develop in our students an awareness of the complexity of the technological revolution that is occurring in our society and an awareness of their own individual role in such a society."

While such goals may be stated differently there is an underlying theme which would represent a consensus. Our expectations for a students development go well beyond the accumulation of facts or even the techniques for solving

complex yet well defined problems. In light of these larger expectations we can examine the consequences of teaching in any given course and furthermore examine the consequences of the current structure of the curriculum. In this study we have explored several questions which have relevance to these issues and have arrived at the following conclusions:

For a narrow range of high ability students there is little or no correlation between academic performance and intellectual aptitudes. Instead a variety of variables that are associated with motivation and attitude account for more of the variability in students academic performance. There is some evidence which suggests that attitudes having to do with perserverence rather than creativity are highly correlated with success in the engineering curriculum.

Although creativity and flexibility are recognized as important ingredients in the problem solving orientation of engineers, there is little evidence of this being a major focus of attention in the training of engineers. Even where an instructor may reveal some of these characteristics in his teaching, there is a lack of follow through when it comes to evaluating the students performance. A wide variety of factors make the student more responsive to what he will be examined on rather than to what he is being taught. This inadvertently leads students to focus on learning in a passive manner rather than actively pursuing the intellectual challenges of the course material.

By instituting a variety of means for students and instructors to communicate with each other, many of the larger goals of the curriculum can be made relevant to any subject. Evaluation of the learning process becomes something that both teacher and student engage in and thus share in a common enterprise.

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APPENDIX

Name John Doe

Date Nov 10, 1965

Today's lecture was good____/ X /____/____/____/ bad.

What was good and/bad about it?

A little unclear as to application to our present project. Interesting though.

The major point(s) of today's lecture was (were):

Stress in brackets

Referring to the material presented in today's lecture I

	X			
Understand it completely	Have good grasp of it with only a few minor uncertainties	Have an idea but still have many weaknesses	Vague notion of what it is about	Am almost totally in the dark

(If several points were covered in the lecture, give additional ratings as necessary, labeling your rating marks.)

Referring to the material of the course as a whole I

	X			
Understand it comppletely	Have good grasp of it with only a few minor uncertainties	Have an idea but still have many weaknesses	Vague notion of what it is about	Am almost totally in the dark

I am enjoying this course

X /____/____/____/____

a great deal — average — not at all

I am ahead (circle one) with my assignments.
behind
on schedule

Please make additional comments, using other side of this page.

Table A Demographic Data

(See Section 4)

		N=17 Group I		N=13 Group II		N=10 Group III	
		f	%	f	%	f	%
Age	16-20	10	59	8	61	4	40
	21-25	7	41	3	23	4	40
	26-30	-	-	2	15	1	10
	older	-	-	-	-	1	10
Class	Fr 1	-	-	-	-	-	-
	Soph 2	4	23	-	-	-	-
	Jr 3	9	53	8	61	4	40
	Sr 4	4	23	4	31	5	50
	Grad 5	-		1	8	1	10
Discipline	Astro 1	1	6	-	-	-	-
	Civil 2	2	12	2	15	-	-
	Elec Physio 3	-	-	1	8	-	-
	EE 4	7	41	2	15	6	60
	Genrl 5	-	-	-	-	2	20
	IE 6	1	6	4	31	1	10
	ME 7	5	29	4	31	1	10
	Physics 8	1	6	-	-	-	-
Plan to Attend Grad School	Yes (1)	9	53	8	61	6	60
	No (2)	2	12	1	8	1	10
	Undec (3)	6	35	3	23	3	30
	No answer	-	-	1	8	-	-

Table A continued

		Group I f	Group I %	Group II f	Group II %	Group III f	Group III %
% Lectures Attended	0 (0)	-	-	-	-	-	-
	25 (1)	-	-	-	-	-	-
	26-50 (2)	-	-	-	-	-	-
	51-75 (3)	1	6	-	-	-	-
	76-100 (4)	16	94	13	100	10	100
Not answered		1	6				
Prob Sessions Attended	0 (1)	1	6	-		1	10
	1 (2)	-		-		-	
	2 (3)	-		1	8	-	
	3-4 (4)	-		3	23	2	20
	5-6 (5)	-		1	8	1	10
	7	15	88	8	61	6	60
Expected Grade	D (1)	1	6	3	23		
	C (2)	8	47	3	23	2	20
	B (3)	7	41	6	46	6	60
	A (4)	1	6	1	8	2	20

Table B

Students' Description of Their Problem Sessions

(See Section 4)

		Group I		Group II		Group III	
		f	%	f	%	f	%
Description Prob Sessions Good	1 (low)	-	-	2	15	2	20
	2	-	-	1	8	1	10
	3	1	6	1	8	-	-
	4	-	-	1	8	1	10
	5	-	-	1	8	2	20
	6	-	-	0	-	1	10
	7	3	18	1	8	-	-
	8	1	6	1	8	-	-
	9 (high)	7	41	2	15	-	-
didn't answer		5	29	3	23	3	30
Description Prob Sessions Bad	1 (low)	-	-	-	-	-	-
	2	-	-	1	8	-	-
	3	-	-	-	-	1	10
	4	-	-	2	15	-	-
	5	-	-	3	23	1	10
	6	2	12	-	-	2	20
	7	1	6	-	-	2	20
	8	-	-	1	8	1	10
	9 (high)	-	-	1	8	1	10
didn't answer		14	82	5	38	2	20

Table C

(See Section 4)

Means and Standard Deviations of

Students' Opinions About Problem Sessions Judged as "Good"

Group

	I	II	III
Mean	5.59	3.77	2.40
SD	3.88	3.35	2.24

Table D

(See Section 4)

Means and Standard Deviations of

Students' Opinions About Problem Sessions Judged "Bad"

Group

	I	II	III
Mean	1.12	3.23	5.10
SD	2.42	3.04	2.98

Table E

Problem-Orientation Questionnaire

(Percent responding true)

(See Section 4)

Group I	Group II	Group III	
6	38	30	Problem sessions are usually a waste of time.
12	31	--	I almost always do more problems than just those that are assigned.
100	100	70	I take study breaks when I am working on a set of problems.
76	100	100	I usually get my problems done and handed in on schedule.
94	92	90	I always review problem solving material just before a test.
88	100	80	The success of problem sessions depends largely on the instructor.
18	54	50	I learn more from talking to fellow students than I do in problem sessions.
88	100	50	If a problem session is taught by the regular lecturer in a course, I try to get into that one, rather than one taught by his assistants, even if they have Ph.D.'s.
59	69	80	Sometimes a good class lecturer isn't very good at teaching problem solving.
--	23	10	Each problem must be approached individually; there is no generally applicable problem solving strategy.
53	84	80	The ability to solve problems is what engineering is all about.
12	15	--	Most professors of engineering are poor teachers.
82	69	50	If a problem stumps me, I keep plugging away at it until I solve it.
59	61	40	I wish that grades were not so totally determined by ability to work problems.
94	46	50	Problem sessions materially contribute to my understanding in a course.
12	8	10	I always try to work sample problems before I do the regular assignment.

Table E Continued

Group I	Group II	Group III	
76	69	70	I rarely consult with an instructor during his office hours.
47	69	70	I usually try to arrive at an intuitive answer to a problem before proceeding with a formal solution.
82	69	70	I resent examinations in which speed of problem solving is a major factor.
82	77	50	Sometimes I get sick and tired of doing nothing but problems.
41	38	40	It is virtually impossible for me to do problems effectively on Saturday night.
12	8	30	I often briefly review the day's work just before I go to bed at night.
12	15	30	I have had practical engineering experience which has contributed to my ability to solve problems.
35	15	40	Examinations in which the grade is determined entirely by the ability to solve problems accurately measure a student's knowledge of the course material.
65	54	30	I really get frustrated when I can't solve an assigned problem.
23	31	10	Instructors should put more emphasis on theory than on solution of problems.
29	38	40	One of the characteristics of good problem solvers is the ability to isolate oneself, sometimes for hours at a time.
82	54	50	Problem sessions usually clear up difficulties I may have had.
6	23	20	I have difficulty going to sleep at night when I have been unable to do some assigned problems.

Table F

Group I Instructor

(See Section 4)

Instructor Ratings %	0	1	2	3	4	5	6	7	Mean
warm--cold		23	12	23	29	--	6	--	2.9
rigid--flexible		--	6	23	12	23	18	12	4.9
sensitive--insentitive		18	47	12	6	6	6	--	2.5
active--passive		47	23	23	--	--	--	--	1.7
no sense of humor--good sense		--	--	6	12	29	23	23	5.5
uninterested in others--interested		6	--	--	23	23	23	18	5.1
dull--lively		--	--	6	12	18	41	18	5.6
comfortable--uncomfortable		12	12	23	18	6	18	6	3.8
encourages discussion--no		12	18	12	20	12	6	6	3.5
not likeable--likeable		--	--	--	--	41	17	35	5.9
good teacher--poor teacher		47	23	6	12	--	--	6	2.1
conventional--unconventional		--	23	29	18	6	--		3.5
unhelpful--helpful		--	--	--	12	23	35	23	5.7
fair--unfair		--	53	23	18	--	--	--	1.6
open minded--close minded		18	41	18	12	6	--	--	2.4
no respect for students--respect		--	--	--	12	23	35	23	5.7
intellectually quick--slow		59	18	6	6	--	6	--	1.2
strong--weak		6	23	41	18	12	--	--	2.2
unrewarding--rewarding		6	--	--	29	18	23	23	5.4

SUMMARY:

Active--good sense of humor--interest in others--likeable--helpful--fair--respect for students--intellectually quick--rewarding.

Table F Continued

Group II Instructor

(See Section 4)

Instructor Ratings %	0	1	2	3	4	5	6	7	Mean
warm--cold		--	15	23	38	8	15	--	3.8
rigid--flexible		--	--	8	31	31	15	15	5.0
sensitive--insentitive		15	31	23	8	15	8	--	3.0
active--passive		15	8	23	46	8	--	--	3.2
no sense of humor--good sense		--	8	23	31	23	15	--	4.1
uninterested in others--interested		--	8	--	31	54	--	8	4.6
dull-lively		8	8	--	62	15	8	--	3.9
comfortable--uncomfortable		--	--	38	23	23	8	8	4.2
encourages discussion--no		[illegible]	15	38	15	8	--	--	2.7
not likeable--likeable		--	8	8	31	23	15	15	4.7
good teacher--poor teacher		15	--	23	23	23	8	8	3.9
conventional--unconventional		--	--	31	54	15	--	--	3.8
unhelpful--helpful		--	8	8	23	31	23	8	4.8
fair--unfair		8	8	15	69	--	--	--	3.5
open minded--close minded		15	15	23	31	15	--	--	3.1
no respect for students--respect		--	--	15	8	38	15	23	5.2
intellectually quick--slow		15	8	38	38	--	--	--	3.0
strong--weak		8	15	--	31	31	8	8	4.1
unrewarding--rewarding		8	8	--	38	46	--	--	4.1

SUMMARY:

Encourages discussion--flexible--sensitive--intellectually quick--respect for students.

Table F Continued

Group III Instructor

(See Section 4)

Instructor Ratings %	0	1	2	3	4	5	6	7	Mean
warm--cold		10	--	10	20	30	10	10	4.4
rigid--flexible		--	20	20	10	20	20	--	4.0
sensitive--insentitive		--	--	30	10	40	--	10	4.4
active--passive		--	30	30	--	10	10	10	3.7
no sense of humor--good sense		--	--	10	30	30	20	--	4.4
uninterested in others--interested		10	10	20	20	20	10	--	3.7
dull-lively		10	--	20	20	40	--	--	3.9
comfortable--uncomfortable		10	--	30	30	10	10	--	3.7
encourages discussion--no		--	10	30	20	10	10	10	4.1
not likeable--likeable		10	--	10	20	40	10	--	4.2
good teacher--poor teacher		--	--	10	30	20	30	--	4.8
conventional--unconventional		10	20	20	20	10	10	--	3.3
unhelpful--helpful		10	10	10	40	20	--	--	3.5
fair--unfair		--	30	40	10	10	--	--	4.0
open minded--close minded		--	20	30	20	20	--	--	3.4
no respect for students--respect		10	10	20	20	20	10	--	3.7
intellectually quick--slow		10	50	20	--	10	--	--	2.4
strong--weak		--	20	30	30	--	10	--	3.4
unrewarding--rewarding		10	10	10	40	20	--	--	3.5

SUMMARY:

Fairly flat--poor teacher, but intellectually quick.

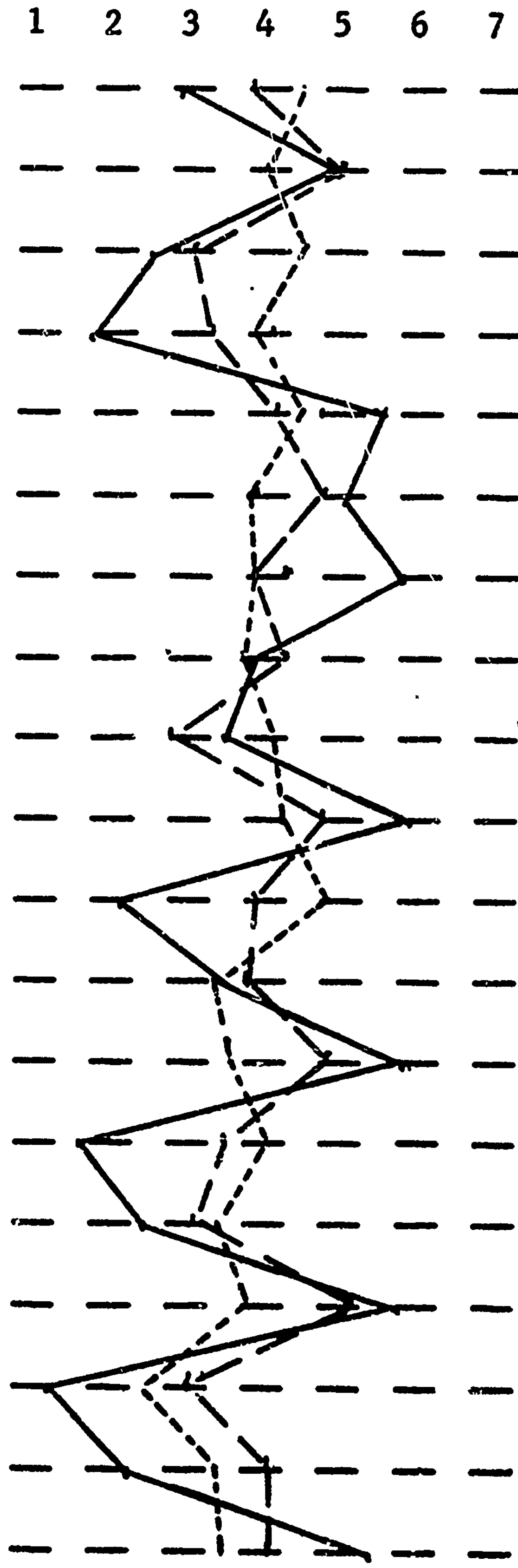
Table F Continued

Group I ———
Group II — — —
Group III - - - - - -

Mean Ratings of the Three Problem Session Instructors:

(See Section 4)

Describe your problem session instructor by placing a mark at the point on the scale which best characterizes him. Indicate a choice for each dimension; do not skip any. Feel free to express your opinions.



warm	cold
rigid	flexible
sensitive to class reactions	insensitive to class reaction
active	passive
no sense of humor	good sense of humor
uninterested in others	interested in others
dull	lively
comfortable	uncomfortable
encourages discussion	discourages discussion
not likeable	likeable
good teacher	poor teacher
conventional	unconventional
unhelpful	helpful
fair	unfair
open minded	close minded
shows no respect for student	shows respect for students
intellectually quick	intellectually slow
strong	weak
unrewarding	rewarding

EXAMPLE OF INTERVIEW FORM

USED IN ENGRG. 42

(See Section 6)

Name________________________________

What influence has this course had on your attitude toward electrical engineering? On your attitude toward engineering in general?

Has this course contributed to your ability to solve engineering problems? (If so) How?

Of what significance is this course with regard to your engineering career?

Does this course relate to others you have had or will have? How? (Particularly E.E. 41)

What do you think of the problem sets? Do they help you to learn the material? Do you review them? How much time do they take?